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Effect of Seed Inoculation, Weed Management and Foliar Nutrition in Rice Fallow Blackgram for Higher Productivity in Cauvery Delta Zone of Tamil Nadu

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ABSTRACT

Background: Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai during 2021-22, 2022-23 and 2023-24 to find out suitable bio inoculant, weed management practice and foliar nutrition for Rice fallow blackgram.

Methods: The experiments were carried out by using RCBD (Factorial) with three replications. The treatments *viz.,* Seed inoculation [A_1- Control (no seed inoculation), A_2- Rhizobium + PSB (local), A_3- LSMR 1 + RB 3 microbial consortia], Weed management [B_1- Weedy check, B_2- Propaquizafop 2.50 % + imazethapyr 3.75 % ME @ 125 g ha^{-1} at 15-20 DAS, B_3- Fomesafen @ 220 g ha^{-1} + fluzifop-p-butyl @ 220 g ha^{-1} at 15-20 DAS] and Foliar nutrition [C_1- Water spray at flower initiation and pod initiation stage, C_2- Nano urea spray @ 0.25 % at flower initiation and pod initiation stage, C_3- 19:19:19 NPK @ 2 % at flower initiation and pod initiation stage].

Result: The lower weed density, weed dry weight and higher weed control efficiency was recorded with application of early post emergence herbicide fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS. Seed inoculation with LSMR1 + RB3 microbial consortia, application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS and foliar nutrition with 19:19:19 NPK @ 2 % at flower initiation and pod initiation stage had taller plants, higher pods plant^{-1}, more seeds pod^{-1} and test weight which led to higher grain yield. Due to increase in blackgram yield, the same treatment achieved higher gross return, net return and benefit cost ratio.

Key words: Blackgram, PSB, Rhizobium, Water soluble fertilizer, Weedicide.

INTRODUCTION

Blackgram (*Vigna mungo* L.) is one of the important pulse crops in India. It is basically a tropical crop and mostly cultivated during rice fallow and summer seasons in Cauvery Delta Zone. The area, production and productivity of blackgram in Tamil Nadu are 4.07 lakhs ha, 2.68 lakhs tonnes and 660 kg ha^{-1} respectively (India Stat, 2022-23). In Tamil Nadu, the Cauvery Delta Zone has a total land area of 1.45 million ha, which is equivalent to 11% of the state area and this zone is the potential zone for pulse cultivation. The major share of pulses in Tamil Nadu in terms of area and production comes from the Cauvery Delta region (Subrahmaniyan *et al.,* 2023). The reasons for low productivity of rice fallow blackgram are less spread of high yielding varieties, non-availability of quality seeds in time, delay in sowing, inadequate plant population, low adoption of improved agronomic practices, lack of foliar nutrient application, heavy weed infestation and inadequate plant protection. Seed treatment can improve seedling establishment and better crop stand, it also improves plant's ability to tolerate stress at early growth stages. The yield and nutritional quality of pulses is greatly influenced by application of phosphorus. It plays a key role in various physiological processes like root growth, dry matter production, nodulation, nitrogen fixation and also in metabolic activities especially in protein synthesis. (Alikhani *et al.,* 2006). The weeds compete for nutrient,

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water, light and space with crop plant during early growth period. Yield losses in blackgram due to weeds have been estimated to range between 50-60% (Das *et al.,* 2014). Weeds are controlled by various methods like cultural, manual, mechanical, biological and chemical methods. Manual and mechanical weeding is labourers intensive and tedious. Many times, labourers are not available at peak time of requirement for weeding. Gogoi *et al.* (1992) reported that the critical period of crop weed competition in blackgram was between 10 and 30 days after sowing. Bhandari *et al.* (2004) observed that in summer blackgram maximum crop weed competition occurred during the period up to 30 days after sowing. The chemical method of weed control is not only cost effective, but also efficient in minimizing weed infestation for longer period provided they are applied judiciously *i.e.* with suitable herbicide in dose and time (Pratap *et al.,* 2021). Foliar application has the advantage of quick and efficient utilization of nutrients, elimination of nutrient losses through leaching and fixation in soil and also helps in regulating the uptake of nutrients by plants thus improving productivity of pulse crops. Supply of nutrients through foliar application during critical stage ensured positive source sink gradient of photosynthates translocation and balanced growth habit (Maheswari *et al.,* 2017). This has been attributed to reduced flower shedding and increase in pod setting, grain filling and ultimately the yield. Under these circumstances, there is a need to develop yield maximization techniques through seed inoculation, weed management and foliar nutrition in blackgram for higher productivity.

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai during 2021-22, 2022-23 and 2023-24 to find out suitable bio inoculant, weed management practice and foliar nutrition for rice fallow black-gram. The experimental site is situated in Cauvery Delta Zone of Tamil Nadu at 11.0° North latitude, 79.4° East longi-tude at an altitude of 19.4 m above mean sea level. The soil of the experimental field was moderately drained, deep clay loam classified taxonomically as *Typic haplustalf*. The available nitrogen was estimated by alkaline permanganate method of Subbiah and Asija (1956) and expressed in kg ha^{-1}. The available phosphorus was estimated by the method of Olsen *et al.* (1954) and expressed in kg ha^{-1}. Available potassium was estimated by neutral normal ammonium acetate extraction and flame photometry developed by Stanford and English (1949) and expressed in kg ha^{-1}. The soil pH was estimated as per the method suggested by Jackson (1973). The soil was low in available nitrogen (275 kg ha^{-1}), high in available phosphorus (46 kg ha^{-1}) and high in available potassium (298 kg ha^{-1}) respectively. The soil was near neutral in reaction with a pH was 7.6. The experiments were laid out in a RCBD (Factorial) with three replications. The blackgram variety 'ADT 6' was utilized for this study during the rice fallow seasons of 2021-22, 2022-23 and 2023-24.

Treatments

Seed Inoculation

A_1: Control (no seed inoculation).
A_2: Rhizobium + PSB (local).
A_3: LSMR 1 + RB 3 (microbial consortia).

Weed management

B_1: Weedy check.
B_2: Propaquizafop 2.50 % + imazethapyr 3.75 % ME @ 125 g ha^{-1} at 15-20 DAS.
B_3: Fomesafen @ 220 g ha^{-1} + fluzifop-p-butyl @ 220 g ha^{-1} at 15-20 DAS.

Foliar Nutrition

C_1: Water spray at flower initiation and pod initiation stage.
C_2: Nano urea spray @ 0.25% at flower initiation and pod initiation stage.
C_3: 19:19:19 NPK @ 2% at flower initiation and pod initiation stage.

The blackgram seed was broadcasted 7 days before harvest of paddy crop in waxy soil condition by using a seed rate of 30 kg ha^{-1}. All bio-inoculants, including Rhizobium (lignite-based), Phosphobacteria (lignite-based) and the microbial consortium LSMR1 + RB3 (talc based), were applied as a seed treatment. Each bio-inoculant was individually mixed at a rate of 1.5 kg ha^{-1} of seeds. Rice gruel was used as a binding agent during the process. The treated seeds were then shade dried for 30 minutes before being sown. Blackgram was cultivated using residual soil moisture and fertility, benefiting from the fertilizer applied to the preceding rice crop at a rate of 150:50:50 kg NPK ha^{-1}. The treatments were imposed as per the treatment schedule. Weed count was recorded at 30 DAS by using 0.25 m^{-2} quadrate at four places in each plot and expressed as number m^{-2} as suggested by Burnside and Wicks (1965). The values were subjected to square root transformation (X+0.5) as described by Bartlett (1947). Growth, yield components and grain yield were recorded at harvest. The experimental data were analyzed statistically as per the method suggested by Gomez and Gomez (1984). Weed control efficiency (WCE) was calculated as suggested by Mani *et al.* (1973) and expressed in percentage.

$$WCE\ (\%) = \frac{\text{Weed dry weight in control plot} - \text{Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}} \times 100$$

RESULTS AND DISCUSSION

Weed density, weed dry weight and weed control efficiency

The mean value of three years (Rice fallow seasons of 2021-22, 2022-23 and 2023-24) result is presented (Table 1) and discussed here under. Significant influence of treatments was observed on weed density, weed dry weight and weed control efficiency. Among the microbial seed

inoculation treatments, rhizobium + PSB (local) (A_2) recorded the lowest total weed density (19.04 weeds m^{-2}), which was statistically similar to the LSMR 1 + RB3 microbial consortia (A_3) treatment. The lowest weed dry weight (12.10 g m^{-2}) was observed with the LSMR 1 + RB3 microbial consortia (A_3) treatment, which was also comparable to the rhizobium + PSB (local) (A_2) treatment. Early plant vigour and higher biomass due to seed treatment would have enabled blackgram to act as a cover crop and supress the weeds. Among the various weed management practices, applying fomesafen + fluazifop-p-butyl at 220 g ha^{-1} at 15-20 DAS had lower weed density of 15.46 weeds m^{-2}, which was comparable with propaquizafop 2.5% + imazethapyr 3.75% ME at 125 g ha^{-1} at 15-20 DAS. Similarly, application fomesafen + fluazifop-p-butyl at 220 g ha^{-1} at 15-20 DAS resulted in weed dry weight of 9.77 g m^{-2} and was comparable with propaquizafop 2.5% + imazethapyr 3.75% ME @ 125 g ha^{-1} at 15-20 DAS. Consequently, higher weed control efficiency of 70.15% was registered with fomesafen + fluazifop-p-butyl at 220 g ha^{-1} at 15-20 DAS and it was followed by propaquizafop 2.5% + imazethapyr 3.75% ME at 125 g ha^{-1} at 15-20 DAS. The higher weed control efficiency was due to lower weed density and lower weed dry weight following effective weed control. A similar result was reported by Yadav *et al.* (2022). Rhizobium + PSB (local) (A_2) had the lowest total weed density (19.04 weeds m^{-2}), which was comparable to the LSMR 1 + RB3 microbial consortia (A_3) treatment. Similarly, the LSMR 1 + RB3 microbial consortia (A_3) treatment recorded the lowest weed dry weight (12.10 g m^{-2}), which was on par with the rhizobium + PSB (local) (A_2) treatment. The LSMR 1 + RB3 microbial consortia (A_3) treatment showed the highest weed control efficiency among the microbial treatments, achieving 49.83%, followed closely by the Rhizobium + PSB (local) (A_2) treatment. In comparison, chemical treatments demonstrated significantly higher efficiency: fomesafen + fluazifop-p-butyl at 220 g ha^{-1} applied 15-20 DAS recorded the highest weed control efficiency at 70.15%, followed by propaquizafop 2.5% + imazethapyr 3.75 ME at 125 g ha^{-1}, also applied at 15-20 DAS. Spraying of 19:19:19 NPK @ 2 % had the higher weed control efficiency of 47.25 % and it was followed by nano urea spray @ 0.25 % (C_2) treatment (Table 1). The interaction effect was not statistically significant.

Growth parameters

Seed inoculation with LSMR1 + RB3 microbial consortia resulted in taller plants of 35.4 cm and it was on par with rhizobium + PSB (local) (Table 2). Similar finding was also reported by Dhyani *et al.* (2011). Application of post emergence herbicide fomesafen + fluzifop-b-butyl @ 220 gha^{-1} at 15-20 DAS effectively reduced weed density and weed dry weight resulting in the tallest plants of 35.5 cm.

The least plant height was observed with weedy check. Foliar spraying of 19:19:19 NPK @ 2% at flower initiation and pod initiation stage significantly increased the plant

Table 1: Effect of treatments on weed density, weed dry weight and weed control efficiency of blackgram at 30 DAS (Mean of three years).

Treatment	Weed density (No. m^{-2})				Total dry weight (g m^{-2})	WCE (%)
	Grasses	Sedges	BLW	Total		
Seed inoculation						
A_1	6.44 (14.51)	5.68 (11.00)	7.70 (20.05)	19.82 (45.61)	13.17 (60.10)	41.28
A_2	6.11 (13.13)	5.50 (10.38)	7.51 (19.10)	19.04 (42.62)	12.22 (52.08)	49.12
A_3	6.23 (13.72)	5.56 (10.58)	7.54 (19.25)	19.36 (43.62)	12.10 (51.35)	49.83
S.Em±	0.02	0.03	0.04	0.09	0.06	-
CD (p=0.05)	0.07	0.08	0.11	0.26	0.19	-
Weed management						
B_1	9.11 (26.42)	7.72 (19.01)	10.27 (33.58)	27.10 (79.03)	17.93 (102.36)	-
B_2	4.87 (7.61)	4.52 (6.51)	6.25 (12.47)	15.66 (26.59)	9.78 (30.61)	70.09
B_3	4.81 (7.33)	4.49 (6.44)	6.24 (12.39)	15.46 (26.22)	9.77 (30.55)	70.15
S.Em±	0.07	0.04	0.05	0.16	0.09	-
CD (p=0.05)	0.12	0.09	0.13	0.35	0.20	-
Foliar nutrition						
C_1	6.24 (13.71)	5.55 (10.54)	7.56 (19.32)	19.36 (43.58)	12.65 (55.34)	45.93
C_2	6.30 (13.92)	5.62 (10.81)	7.63 (19.73)	19.50 (44.53)	12.44 (54.19)	47.05
C_3	6.25 (13.74)	5.57 (10.61)	7.57 (19.38)	19.36 (43.73)	12.40 (53.99)	47.25
S.Em±	0.06	0.05	0.07	0.19	0.12	-
CD (p=0.05)	NS	NS	NS	NS	NS	-

Figures in parenthesis are the original values and others are square root log transformed values.

A_1: Control, A_2: Rhizobium + PSB (local), A_3: LSMR 1 + RB 3 (microbial consortia). B_1: Weedy check, B_2: Propaquizafop 2.50 % + imazethapyr 3.75 % ME @ 125 g ha^{-1} at 15-20 DAS, B3: Fomesafen @ 220 g ha^{-1} + fluzifop-p-butyl @ 220 g ha^{-1} at 15-20 DAS. C_1: Water spray at flower initiation and pod initiation stage. C_2: Nano urea spray @ 0.25 % at flower initiation and pod initiation stage, C_3: 19:19:19 NPK @ 2 % at flower initiation and pod initiation stage.

height recording 37.7 cm at harvest stage. The increase in plant height might be due to the internodal elongation and the vigorous root growth of the crop. Similar result was reported by Kumar *et al.* (2018). The interaction effect was not statistically significant.

Yield attributes

Seed inoculation with LSMR1 + RB3 microbial consortia resulted in more number of pods plant^{-1} (24.4). Application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS resulted in more number of pods (23.6 plant^{-1}). Among the foliar nutrient application, the higher number of pods plant^{-1} (23.4) was with spraying of 19:19:19 NPK @ 2% at flower initiation and pod initiation stage. Timely supply of nutrients through foliar spray during peak nutrient demand might have reduced the shedding of flowers resulting in higher number of pods. Similar result was earlier reported by Ashraf *et al.* (2024). Seed inoculation with LSMR1 + RB3

Table 2: Effect of treatments on growth and yield attributes and grain yield of blackgram (Mean of three years).

Treatment	Plant height at harvest (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Grain yield (kg ha^{-1})
Seed inoculation					
A_1	33.9	20.2	4.55	3.74	752
A_2	35.3	24.2	4.81	4.25	844
A_3	35.4	24.4	6.03	4.86	856
S.Em±	0.15	0.05	0.03	0.26	5.6
CD (p=0.05)	0.41	0.16	0.10	0.72	15.5
Weed management					
B_1	34.2	21.9	4.95	4.11	758
B_2	34.9	23.3	5.08	4.3	839
B_3	35.5	23.6	5.35	4.45	854
S.Em±	0.2	0.09	0.04	0.03	8.4
CD (p=0.05)	0.45	0.21	0.09	0.06	18.0
Foliar nutrition					
C_1	31.8	22.3	4.89	4.05	762
C_2	35.1	23.0	5.04	4.33	828
C_3	37.7	23.4	5.46	4.47	862
S.Em±	0.22	0.15	0.04	0.03	9.0
CD (p=0.05)	0.45	0.32	0.09	0.06	18.4

A_1: Control, A_2: Rhizobium + PSB (local), A_3: LSMR 1 + RB 3 (microbial consortia). B_1: Weedy check, B_2: Propaquizafop 2.50% + imazethapyr 3.75 % ME @ 125 g ha^{-1} at 15-20 DAS, B_3: Fomesafen @ 220 g ha^{-1} + fluzifop-p-butyl @ 220 g ha^{-1} at 15-20 DAS. C_1: Water spray at flower initiation and pod initiation stage. C_2: Nano urea spray @ 0.25 % at flower initiation and pod initiation stage, C_3: 19:19:19 NPK @ 2% at flower initiation and pod initiation stage.

Table 3: Effect of treatments on economics of blackgram (Mean of three years).

Treatment	Total cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B: C ratio
Seed inoculation				
A_1	20426	56400	35974	2.76
A_2	20626	63300	42674	3.07
A_3	20582	64200	43618	3.12
Weed management				
B_1	20177	56850	36673	2.82
B_2	20602	62925	42323	3.05
B_3	20675	64050	43375	3.10
Foliar nutrition				
C_1	20342	57150	36808	2.81
C_2	20592	62100	41508	3.02
C_3	20520	64650	44130	3.15

A_1: Control, A_2: Rhizobium + PSB (local), A_3: LSMR 1 + RB 3 (microbial consortia). B_1: Weedy check, B_2: Propaquizafop 2.50% + imazethapyr 3.75% ME @ 125 g ha^{-1} at 15-20 DAS, B3: Fomesafen @ 220 g ha^{-1} + fluzifop-p-butyl @ 220 g ha^{-1} at 15-20 DAS. C_1: Water spray at flower initiation and pod initiation stage. C_2: Nano urea spray @ 0.25% at flower initiation and pod initiation stage, C_3: 19:19:19 NPK @ 2 % at flower initiation and pod initiation stage.

microbial consortia recorded significantly higher number of seeds pod^{-1} (6.03) followed by rhizobium + PSB (local). Application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS resulted in highest number of seeds pod^{-1} of 5.35 followed by propaquizafop 2.5% + imazethapyr 3.75 ME @ 125 g ha^{-1} at 15-20 DAS. Spraying of 2% 19:19:19 NPK at flower initiation and pod initiation stage recorded significantly higher number of seeds pod^{-1} of 5.46.

The foliar nutrients might have supplemented the nutrient demand of the crop at the critical stage, resulting in better growth and development of the crop and ultimately enhanced the yield attributing characters and promoted a positive source sink gradient of photosynthates translocation guaranteeing seed formation and better grain filling (Manivannan *et al.,* 2002). The highest test weight of 4.86 g was recorded with LSMR1 + RB3 microbial consortia. Among the different herbicides tested, application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS (B3) treatment resulted the highest test weight of 4.45 g and it was followed by propaquizafop 2.5% + imazethapyr 3.75 ME @ 125 g ha^{-1} at 15-20 DAS. Among the foliar nutrition, spraying of 2% 19:19:19 NPK at flower initiation and pod initiation stage had the highest test weight of 4.47 g which could be attributed to the production of bold seeds. The interaction effect was not statistically significant.

Grain yield

Among the seed inoculation, LSMR1 + RB3 microbial consortia resulted in higher grain yield of 856 kg ha^{-1} though it was comparable with rhizobium + PSB. Yield enhancement in blackgram following seed treatment with combined application of rhizobium and PSB was also reported by Kant *et al.* (2016). The higher grain yield of 854 kg ha^{-1} was obtained with application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS, which was on par with propaquizafop 2.5% + imazethapyr 3.75 ME @ 125 g ha^{-1} at 15-20 DAS. The application of new generation herbicides at early growth stage of blackgram might have resulted in lesser crop-weed competition for nutrients, which ultimately increased the yield. Similar result was also reported by (Patidar *et al.* 2023). The lowest grain yield was recorded with weedy check (B_1) treatment. Among the foliar nutrition, spraying of 2% 19:19:19 NPK at flower initiation and pod initiation stage (C_3) resulted in higher grain yield of 862 kg ha^{-1}. The yield increase was mainly due to significant improvement in number of pods plant^{-1} and test weight. The result was in accordance with Vijayakumar *et al*. (2021). The lowest grain yield was recorded with water spray (F_1) (Table 2). The interaction effect was not statistically significant.

Economic analysis

Seed inoculation with LSMR1 + RB3 microbial consortia (A_3) resulted in higher gross income (Rs.64200 ha^{-1}), net income (Rs.43618 ha^{-1}) and benefit cost ratio of 3.12 mainly due to higher grain yield of blackgram. Application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS (B_3) enhanced the gross income (Rs.64050 ha^{-1}), net income (Rs.43375 ha^{-1}) and benefit cost ratio of 3.10. The higher gross income (Rs.64650 ha^{-1}), net income (Rs.44130 ha^{-1}) and benefit cost ratio (3.15) were obtained with spraying of 2% 19:19:19 NPK at flower initiation and pod initiation stage (C3) (Table 3).

CONCLUSION

The present study clearly shows that seed inoculation with LSMR1 + RB3 (microbial consortia) with application of fomesafen + fluzifop-b-butyl @ 220 g ha^{-1} at 15-20 DAS and foliar nutrition with 19:19:19 NPK @ 2 % at flower initiation and pod initiation stage could be the best management strategy for blackgram under Cauvery Delta Zone to attain higher productivity and profitability.

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Conflict of interest

All authors declared that there is no conflict of interest.

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