The Andhra Agric. J 70 (2): 153-160, 2023
10.61657/aaj.2023.23

Pre- and Post-emergence Herbicides for Weed Control in Direct Sown Rice and their Residual effect on Succeeding Greengram

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ABSTRACT

In the present study optimisation of growth conditions of *L. acidophilus* MTCC 10307 in alginate beads was carried out with regard to substrate (growth media constituents- sorbitol, cocoa powder and corn starch), temperature (36, 38 and 40!) and inoculum concentration (100, 200 and 300µl). The study revealed that the maximum number of probiotic cells was found in sorbitol containing beads with the viability of 50.66×10^8 CFU/g (9.70 log CFU/g) than cocoa powder and corn starch. The optimum temperature reported was 38! (9.70 log CFU/g) and maximum probiotic count of 85.33×10^8 CFU/g (9.93 log CFU/g) was observed in encapsulated bead inoculated with 300µl of bacterial suspension. Microcapsule prepared with these conditions may help to protect, isolate and control the release of probiotics which is of growing interest in many sectors of food product development.

Key words: *Direct sown rice, Greengram, Herbicides, Seed yield, Uptake, Haulm yield and Drymatter accumulation*

Rice is cultivated in 111 countries of all continents, except Antarctica. India and China are the leading producers as well as consumers of rice. In India, rice is grown in an area of 44.1 million hectares with a production of 108.9 million tonnes and productivity of 2391 kg ha^{-1}. In Andhra Pradesh, it is grown in an area of 2.4 million hectares with a production of 7.24 million tonnes and productivity of 3022 kg ha^{-1} (Ministry of Agriculture, Government of India, 2016-17). Cereal-cereal crop sequences are more exhaustive and put heavy demand on soil resources as compared to cereal-legume and cereal-oilseed sequences along with adverse effect on soil condition (Kumar and Yadav, 1993). Legumes are reported to have favourable impact on the soil fertility and help in increasing the yield of succeeding rice crop (Quayyum and Maniruzzaman, 1996). Inclusion of pulses, oilseeds and vegetables in the system has been found more beneficial than cereal after cereal (Kumpawat, 2001; Raskar and Bhoi, 2001).

Rice-greengram (cereal-legume) sequence is an age old and one of the best cropping sequence followed in the Krishna Agro-climatic Zone of Andhra Pradesh, India. The potential for increasing the productivity of both of these crops *i.e.,* rice and greengram in sequence is tremendous with proper weed management practices. Cultivation of pulses in rice fallows involves sowing of pulse seed by broadcast in the standing rice crop (relay cropping), 2-3 days before it's harvest. The crop survival depends on residual effect of herbicides which were applied to preceding crop thus sown survives entirely on the residual moisture and fertility. The productivity of the crop in this system is often limited by poor crop stand, weed menace and terminal moisture stress. Thus, the significance of optimum plant population, rationalization of moisture supply and weed management under rice fallow conditions have to be investigated to increase the productivity of rice fallow greengram. Keeping above facts in mind, an attempt has been made to study the efficacy of sequential application of herbicides in direct sown rice and their residual effect on succeeding greengram.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural College Farm, Bapatla, Guntur, Andhra Pradesh. The soil of experimental field was sandy loam in texture. The experiment was conducted for two successive *kharif* and *rabi* of 2015-16 and 2016-

17 in Krishna Agro-climatic Zone of Andhra Pradesh. There were fourteen treatments were randomly allocated and replicated thrice in Randomized Complete Block design as mentioned below.

Treatments	Dose (g ha-1)	Time (DAS)
T_1. Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post
T_2. Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post
T_3. Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post
T_4. Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post
T_5. Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post
T_6. Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post
T_7. Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post
T_8. Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post
T_9. Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post
T_{10}. Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post
T_{11}. Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post
T_{12}. Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post
T_{13}. Weed free	-	-
T_{14}. Weedy check	-	-

Note: Weed free condition maintained by employing manual weeding at regular intervals

Greengram plants enclosed in an area of 0.25 m^2 from the sampling area were removed at maturity. The plant samples so collected were sundried and later oven dried at 60^0C till a constant weight was obtained. The data was computed and expressed in kg ha^{-1}. The total number of pods was counted from the ten randomly selected plants in the net plot area and averaged $plant^{-1}$. At maturity all the above ground greengram biomass from each net plot area was harvested and transported to the threshing floor. After drying in sun for seven days, the biomass from each plot was weighed before subjecting it for threshing. After threshing, weight of grain was recorded plot-wise and expressed in kg ha^{-1}.

Uptake was calculated by multiplying the nutrient content with the respective dry matter weight of grain and straw, which were summed up to estimate total nutrient uptake at harvest.

Nutrient uptake (kg/ha) =

Nutrient concentration (%) x weight of dry matter (kg/ha)/100

Statistical analysis for drymatter partitioning and yield parameters were done by following the analysis of variance technique suggested by Gomez and Gomez (1984). Statistical significance was tested by applying F-test at 0.05 level of probability and critical difference (CD) were calculated for those parameters.

RESULTS AND DISCUSSION

Drymatter accumulation of greengram at harvest (kg ha^{-1})

Drymatter accumulation in the sequence greengram crop was recorded at maturity during both the years of study and the same was tabulated, analyzed and presented in Table 2. The results indicated that weed management practices had no influence on drymatter accumulation of the succeeding greengram crop at harvest. This indicates that the residual effects of herbicides may not be for longer periods and they will not influence the growth of the succeeding crop.

Number of pods $plant^{-1}$

The number of pods $plant^{-1}$ in greengram was not influenced by the weed management practices done in rice in both the years of study.

Table 1. Drymatter accumulation (kg ha^{-1}) and number of pods plant^{-1} of greengram at harvest as influenced by weed management practices in rice-greengram sequence during 2015-16 and 2016-17 *rabi* season

Treatments	Dose (g ha^{-1})	Time (DAS)	Dry matter accumulation		Number of pods plant^{-1}	
			2015	2016	2015	2016
$T_{1.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post	1785	2128	19.3	20.9
$T_{2.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	1752	2197	18.6	19.2
$T_{3.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	1798	2253	19.6	19.2
$T_{4.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	1731	2197	19.4	18.4
$T_{5.}$ Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post	1690	2148	18.7	18.2
$T_{6.}$ Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	1684	2061	18.0	18.6
$T_{7.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	1857	2197	19.6	19.0
$T_{8.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	1814	2171	19.3	18.1
$T_{9.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	1833	2277	20.2	20.6
$T_{10.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	1813	2245	19.5	19.5
$T_{11.}$ Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	1782	2202	19.2	19.4
$T_{12.}$ Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	1770	2183	19.1	20.0
$T_{13.}$ Weed free	-	-	1863	2311	21.1	20.3
$T_{14.}$ Weedy check	-	-	1681	1998	17.8	18.2
SEm ±	-	-	70	71	0.7	0.8
CD (P = 0.05)	-	-	NS	NS	NS	NS

Table 2. Seed yield and haulm yield of greengram as influenced by weed management practices in rice greengram sequence during 2015-16 and 2016-17 *rabi* season

Treatments	Dose (g ha^{-1})	Time (DAS)	Seed yield (kg ha^{-1})		Haulm yield (kg ha^{-1})	
			2015	2016	2015	2016
$T_{1.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post	548	632	1041	1277
$T_{2.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	532	624	972	1274
$T_{3.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	556	652	1106	1303
$T_{4.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	548	548	1035	1207
$T_{5.}$ Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post	537	625	923	1408
$T_{6.}$ Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	529	617	1019	1237
$T_{7.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	559	652	1063	1187
$T_{8.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	537	655	997	1286
$T_{9.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	571	662	1072	1280
$T_{10.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	565	656	1064	1272
$T_{11.}$ Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	530	649	964	1263
$T_{12.}$ Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	534	642	957	1293
$T_{13.}$ Weed free	-	-	585	662	1057	1298
$T_{14.}$ Weedy check	-	-	523	594	976	1253
SEm ±	-	-	19	31	49	99
CD (P = 0.05)	-	-	NS	NS	NS	NS

Table 3. Nitrogen uptake (kg ha^{-1}) at harvest of greengram as influenced by different weed man agement practices in rice-greengram sequence during 2015-16 and 2016-17 *rabi* season

Treatments	Dose (g ha^{-1})	Time (DAS)	2015		2016	
			Grain	Haulm	Grain	Haulm
$T_{1.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post	18.0	8.9	21.7	10.6
$T_{2.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	18.0	8.5	20.6	10.7
$T_{3.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	18.7	9.3	21.3	11.0
$T_{4.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	18.1	8.9	18.4	10.4
$T_{5.}$ Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post	17.6	7.7	21.2	11.9
$T_{6.}$ Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	18.1	8.7	20.5	10.8
$T_{7.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	19.1	8.9	21.1	10.3
$T_{8.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	18.1	8.3	22.0	10.7
$T_{9.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	18.7	9.2	22.4	11.0
$T_{10.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	18.7	8.8	22.0	10.9
$T_{11.}$ Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	18.2	8.5	21.6	10.5
$T_{12.}$ Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	18.1	8.2	21.5	10.7
$T_{13.}$ Weed free	-	-	19.1	9.0	22.0	11.4
$T_{14.}$ Weedy check	-	-	17.5	8.1	19.9	11.0
SEm ±	-	-	0.7	0.5	1.1	0.8
CD (P = 0.05)	-	-	NS	NS	NS	NS

Table 4. Phosphorus uptake (kg ha^{-1}) at harvest of greengram as influenced by different weed management practices in rice-greengram se quence during 2015-16 and 2016-17 *rabi* season

Treatments	Dose (g ha^{-1})	Time (DAS)	2015		2016	
			Grain	Haulm	Grain	Haulm
T_1. Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post	2.0	2.3	2.5	2.9
T_2. Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	1.8	2.1	2.3	2.8
T_3. Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	1.9	2.7	2.6	3.2
T_4. Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	1.8	2.3	2.2	2.5
T_5. Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post	1.8	2.1	2.4	3.1
T_6. Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	1.9	2.2	2.3	2.8
T_7. Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	1.8	2.4	2.5	2.6
T_8. Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	1.8	2.1	2.5	3.1
T_9. Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	2.0	2.3	2.6	3.0
T_{10}. Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	2.1	2.4	2.7	3.0
T_{11}. Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	1.8	2.2	2.6	2.8
T_{12}. Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	1.8	2.2	2.5	3.1
T_{13}. Weed free	-	-	2.3	2.3	2.7	3.1
T_{14}. Weedy check	-	-	1.9	2.2	2.4	2.9
SEm ±	-	-	0.1	0.1	0.2	0.3
CD (P = 0.05)	-	-	NS	NS	NS	NS

Table 5. Potassium uptake (kg ha^{-1}) at harvest of greengram as influenced by different weed management practices in rice-greengram se quence during 2015-16 and 2016-17 *rabi* season

Treatments	Dose (g ha^{-1})	Time (DAS)	2015		2016	
			Grain	Haulm	Grain	Haulm
$T_{1.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron	25 *fb* 20	Pre *fb* Post	6.2	18.0	7.2	21.3
$T_{2.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	5.9	16.1	7.2	20.6
$T_{3.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	6.3	18.4	7.2	21.9
$T_{4.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	6.1	17.2	6.1	20.0
$T_{5.}$ Oxadiargyl *fb* Azimsulfuron	75 *fb* 20	Pre *fb* Post	6.1	15.8	7.1	23.6
$T_{6.}$ Oxadiargyl *fb* Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	6.1	17.1	7.1	20.2
$T_{7.}$ Pyrazosulfuron ethyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	6.3	18.0	7.4	19.6
$T_{8.}$ Pyrazosulfuron ethyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	5.9	17.1	7.3	21.7
$T_{9.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	6.4	18.1	7.7	20.8
$T_{10.}$ Bensulfuron methyl + Pretilachlor with safener *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	6.3	17.5	7.4	21.3
$T_{11.}$ Oxadiargyl *fb* Azimsulfuron *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	6.0	16.2	7.2	20.9
$T_{12.}$ Oxadiargyl *fb* Bispyribac-sodium *fb* Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	6.0	16.0	7.2	20.8
$T_{13.}$ Weed free	-	-	6.4	18.0	7.5	21.9
$T_{14.}$ Weedy check	-	-	5.8	16.5	6.8	21.1
SEm ±	-	-	0.2	0.9	0.3	1.6
CD (P = 0.05)	-	-	NS	NS	NS	NS

Seed yield of greengram (kg ha^{-1})

The seed yield of succeeding greengram crop after rice was non significant among the treatments during both the years of study. This indicates that there was no marked difference among the treatments and the impact of herbicides applied to rice. The applied herbicides which sufficiently got degraded in the soil had no residual effect left to effect the germination, dry matter, number of pods as well as seed and haulm yields of greengram. This phenomenal manifestation indicate that the different weed management practices applied to rice had no adverse or favourable effect on growth and yield of succeeding greengram crop. Similar results were also reported by Kumaran *et al.* (2015) that herbicides applied to rice crop had no residual effect on succeeding crops growth and yields.

Haulm yield (kg ha^{-1})

The haulm yield of succeeding greengram crop was also non significant during the both the years of study, which indicated that the sequentially applied herbicides to rice had no effect on succeeding greengram haulm yield. This might be due to no residual effect of herbicides and their persistence in the soil to effect the succeeding crop.

Nutrient uptake by greengram

Nitrogen, phosphorous and potassium uptake (kg ha^{-1}) estimated at harvest of greengram was not significantly influenced by herbicidal treatments taken up in preceding rice crop during both the years of study. This indicated there was no residual effect of weed management practices on the succeeding crop. Studies on succeeding greengram crop grown after rice revealed that the weed management practices had exhibited no significant impact on growth, dry matter accumulation, yield and nutrient uptake by crop.

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Received on 25.03.2023 and Accepted on 13.05.2023