Weed Management Practices for Yield and Sustainability in Green Gram

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ABSTRACT

A field experiment was conducted from December 2020 to March 2021 in a rice fallow under the Department of Agronomy, College of Agriculture, Vellanikkara to develop a viable weed management strategy in green gram. The lowest weed dry matter production was recorded in hand weeded plots, which was followed by the treatments where pre-emergence application of oxyfluorfen, imazethapyr, imazethapyr + imazamox and diclosulam was integrated with hand weeding. Grain yield and haulm yield was the highest in hand weeding, which was statistically on par with all the treatments where pre-emergence herbicide application was followed by hand weeding. The application of pre-emergence herbicides resulted in a reduction in the soil microbial count at flowering as compared to the untreated plots, however, the microbial population was recovered by harvest stage in the plots treated with oxyfluorfen, imazethapyr and imazethapyr + imazamox. Only diclosulam was found to have a pronounced inhibitory effect on the soil microbial population at harvest stage. Soil nutrient status was found to be higher in any of the weed management treatments as compared to unweeded control.

Keywords : Diclosulam, Green gram, Imazethapyr, Imazethapyr + imazamox, Oxyfluorfen, Soil microbial population

GREEN gram is a short duration, *kharif* season pulse crop, which can be cultivated in *rabi* and summer seasons as well. Green gram has an important place in nutritional security as it is a rich source of protein (25 per cent), riboflavin, thiamine and ascorbic acid. India ranks first in the production of green gram with an area of 4.58 M ha, production of 2.50 Mt and productivity of 548 kg / ha (India Agri Stat, 2019-20). However, there has not been any prominent increase in the productivity of green gram in the country over the last few years, which is a direct result of various biotic and abiotic stresses. Weeds are the major biotic constraints that hinder pulse crops like green gram from achieving their complete production potential. They not only affect the crop directly by competing with resources and reducing the yield, but also make intercultural operations laborious and harbour many disease causing organisms and pests.

Herbicides are being widely used for weed management owing to their high efficiency and reduced labour costs. In India, there had been a threefold increase in the use of herbicides within 10 years from 2005-2015 without much increase in the area under cultivation (Gupta *et al.*, 2017). Pre-emergence herbicides like pendimethalin and oxyfluorfen and post-emergence herbicides like quizalofop-ethyl and fenoxaprop-ethyl are commonly being used to control weeds in green gram and other pulse crops. However, continuous use of herbicides results in problems like environmental contamination and resistance development. Also, herbicides are bio-active compounds which can alter the population and activities of micro-organisms and affect the ecological balance and productivity of agricultural soils (Latha and Gopal, 2010). Hence, there arises a need to develop an economically viable weed management strategy that can successfully lower the weed population below the economic threshold levels without causing much damage to the ecosystem.

MATERIAL AND METHODS

A field trial was carried out from December 2020 to March 2021 in a rice fallow under the Department of Agronomy, College of Agriculture, Vellanikkara, which experiences a warm humid climate. The field is located at a latitude of 10° 31¹ N and longitude of 76° 13¹ E, and is situated 40.3 m above Mean Sea

Level. The soil of the experimental field is sandy loam in texture and acidic in reaction with a pH of 4.27. The soil is medium in organic carbon (0.53%) and available phosphorus (37.5 kg / ha) and low in available nitrogen (75.6 kg / ha) and potassium (93.5 kg / ha). The experiment was laid out in randomized block design and included eight treatments in three replications. The weed management practices evaluated were : stale seed bed for 14 days followed by (*fb*) shallow digging (T_1), stale seed bed for 14 days *fb* shallow digging *fb* oxyfluorfen at 0-3 DAS (T_2), oxyfluorfen at 0-3 DAS *fb* hand weeding at 25 DAS (T_3), imazethapyr at 0-3 DAS *fb* hand weeding at 25 DAS (T_4), imazethapyr + imazamox at 0-3 DAS *fb* hand weeding at 25 DAS (T_5), diclosulam at 0-3 DAS *fb* hand weeding at 25 DAS (T_6) and hand weeding at 20 DAS and 40 DAS (T_7). An unweeded control (T_8) was also included. After ploughing and levelling of the field, seed bed preparation was done in individual plots of size of 20 m^2 (5 m × 4 m). Seeds of short duration green gram variety CO 8 were sown at a spacing of 25 cm x 15 cm. The recommended dose of N, P and K of 20:30:30 kg / ha (KAU, 2016) was supplied using urea, factamphos and murate of potash. Harvesting of the mature pods was done after 65 DAS and was completed in three rounds of picking. Observations on weed dry matter production at 45 DAS and grain and haulm yield of green gram was recorded. Soil microbial population was estimated before sowing, at flowering and at harvest by using serial dilution technique (Johnson and Curl, 1972) and was expressed in cfu/g. Nutrient Agar medium, Kenknight's Agar medium and Rose Bengal Agar medium were used for estimating the count of bacteria, actinomycetes and fungi, respectively. Also, soil nutrient status was analysed before and after the experiment.

RESULTS AND DISCUSSION

Weed Spectrum

Melochia corchorifolia, a broad leaved weed was the predominant weed species identified and accounted for more than 75 per cent of the total weed population. Other dominant broad leaved weeds were *Aeschynomene indica, Grangea maderaspatana, Phyllanthus amara, Heliotropium indicum, Mimosa invisa* and *Mimosa pudica*. Grasses included *Brachiaria mutica, Digitaria ciliaris, Echinochloa colona, Oryza sativa* and *Cynodon dactylon*.

Weed Density

Weed density was the lowest in hand weeding (Table 1), which might be due to the efficient control of weeds achieved through the timely hand weedings undertaken. The total weed count was statistically on par with each other in stale seed bed *fb* oxyfluorfen and all the treatments where pre-emergence herbicide application was integrated with hand weeding, indicating that these integrated weed management practices also ensured satisfactory weed control in green gram. However, comparatively higher weed count was recorded in unweeded control. Similar

TABLE 1

Effect of weed management practices on weed density and dry matter production

Treatments	Weed density (no./m^2)	Weed dry matter production (g/m^2)
SSB for 14 days	8.46 ^{b} (72.00)	16.14 ^{a} (260.67)
SSB for 14 days, *fb* oxyfluorfen at 0-3 DAS	5.09 ^{c} (26.00)	7.07 ^{b} (50.47)
Oxyfluorfen at 0-3 DAS, *fb* HW at 25 DAS	4.83 ^{c} (23.33)	3.30 ^{c} (10.94)
Imazethapyr at 0-3 DAS, *fb* HW at 25 DAS	5.16 ^{c} (26.67)	3.60 ^{c} (13.13)
Imazethapyr + imazamox (RM) at 0-3 DAS, *fb* HW at 25 DAS	4.36 ^{c} (19.33)	2.82 ^{c} (8.10)
Diclosulam at 0-3 DAS, *fb* HW at 25 DAS	4.71 ^{c} (22.67)	2.77 ^{c} (7.74)
HW at 20 DAS and 40 DAS	2.73 ^{d} (8.00)	1.67 ^{d} (3.12)
Unweeded	13.79 ^{a} (190.67)	17.17 ^{a} (295.17)
SE m (±)	0.37	0.39
CD (0.05)	1.15	1.21

* $\sqrt{(x + 0.5)}$ transformed values with original values in parantheses. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT

findings were reported by Kaur *et al.* (2009) and Singh *et al.* (2019) as well.

Weed Dry Matter Production

The lowest weed dry matter production was recorded in hand weeding (3.12 g / m^2), which might be attributed to the fact that the two hand weedings done during the critical stages of crop-weed competition ensured maximum control of both broad leaved weeds and grasses, thereby providing a nearly weed-free condition throughout the cropping season. Similar observations were reported by Singh *et al.* (2017) and Verma *et al.* (2017). The weed dry matter production was statistically on par with each other in all the treatments where herbicide application was integrated with hand weeding, with an average dry matter production of 9.98 g / m^2. The low weed biomass in these treatments might be due to the high efficiency of pre-emergence herbicides in suppressing the initial flushes of weed growth and the control of weeds which emerged later ensured by hand weeding. Natarajan *et al.* (2003) and Thirumalaivasan *et al.* (2016) also opined that the integration of pre-emergence herbicides with hand weeding could result in a significant reduction in weed density and dry matter production. The highest weed dry matter production was observed in unweeded control (295.17 g/m^2) and stale seed bed (260.67 g/m^2) (Table 1 and Fig. 1).

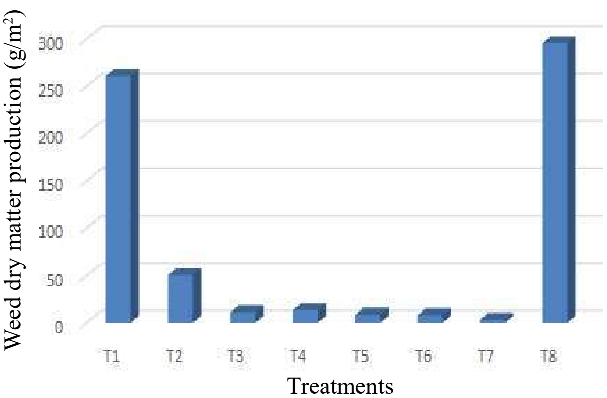

Fig. 1 : Effect of weed management practices on weed dry matter production

Grain and Haulm Yield

The highest grain (1.16 kg / plot) and haulm yield (2.80 kg / plot) was registered in the hand weeding, which was statistically on par with all the treatments where herbicide application was integrated with hand weeding (Table 2 and Fig. 2). The timely weed management practices taken up in these plots might have reduced the competitive interaction of the crop with the weeds and resulted in a more efficient utilization of resources like light, space, nutrients and

TABLE 2

Effect of weed management practices on grain and haulm yield of green gram

	Treatments	Grain yield (kg/ plot)	Haulm yield (kg/ plot)
T_1	SSB for 14 days	0.84 ^{c}	1.99 ^{c}
T_2	SSB for 14 days, fb oxyfluorfen at 0-3 DAS	0.96 ^{bc}	2.28 ^{bc}
T_3	Oxyfluorfen at 0-3 DAS, fb HW at 25 DAS	1.01 ^{abc}	2.48 ^{abc}
T_4	Imazethapyr at 0-3 DAS, fb HW at 25 DAS	1.01 ^{abc}	2.48 ^{abc}
T_5	Imazethapyr + imazamox (RM) at 0-3 DAS, fb HW at 25 DAS	1.10 ^{ab}	2.59 ^{bc}
T_6	Diclosulam at 0-3 DAS, fb HW at 25 DAS	1.07 ^{ab}	2.54 ^{bc}
T_7	HW at 20 DAS and 40 DAS	1.16 ^{a}	2.80 ^{bc}
T_8	Unweeded control	0.35 ^{d}	0.95 ^{d}
SE m (±)		0.06	0.17
CD (0.05)		0.18	0.51

In a column, mean followed by common letters do not differ significantly at 5 % level in DMRT.

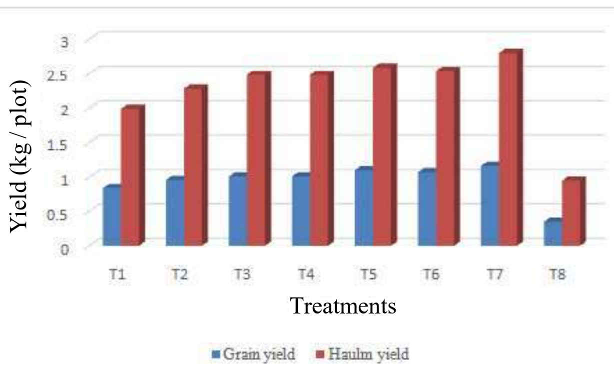

Fig. 2 : Effect of weed management practices on grain and haulm yield in green gram

moisture, which eventually led to an increase in the rate of photosynthesis and metabolic activities, thereby enhancing the overall growth and finally the yield. Grain yield (0.35 kg / plot) and haulm yield (0.95 kg / plot) were invariably the lowest in unweeded control. Dash and Behera (2018) also opined that both the grain yield and haulm yield of green gram was significantly increased when either physical or chemical weeding was employed.

Soil Microbial Population

The total count of bacteria, fungi and actinomycetes showed a steady increase from before sowing to flowering and harvest, with comparatively lower populations observed in herbicide treated plots. However, the total count of actinomycetes was not influenced by weed management practices. At flowering, the highest count of bacteria was observed in hand weeding as compared to herbicide treated plots, which was most likely due to the toxic effect of the pre-emergence herbicides that created conditions unfavourable for the survival of soil bacteria. Singh *et al.* (2020) observed that the soil microbial load was significantly higher in hand weeded plots compared to those which received herbicidal treatments. At harvest also, bacterial population was the highest in hand weeding, but it was statistically on par with imazethapyr + imazamox *fb* hand weeding, unweeded control, oxyfluorfen *fb* hand weeding, stale seed bed, imazethapyr *fb* hand weeding and stale seed bed *fb* oxyfluorfen (Table 3 and Fig. 3). It might be due to the gradual degradation of pre-emergence herbicides in soil which led to a decrease in their final concentration. Singh and Singh (2020) stated that acute toxic effects of herbicides on soil microflora was noticed immediately after herbicide application in green gram, which diminished later due to subsequent decomposition of the chemical and a recovery of soil microbial population. Total fungal count at flowering was the

TABLE 3

Effect of integrated weed management practices on soil microbial population (cfu/g)

Treatments	Bacteria (cfu/g)		Fungi (cfu/g)		Actinomycetes (cfu/g)	
	At flowering	At harvest	At flowering	At harvest	At flowering	At harvest
T_1 SSB for 14 days	*7.14 ^{ab} (14.00×10^{6})	7.41 ^{a} (26.33×10^{6})	5.27 ^{ab} (18.67×10^{4})	5.48 ^{a} (30.67×10^{4})	5.26 (2.00×10^{5})	5.46 (3.00×10^{5})
T_2 SSB for 14 days, *fb* oxyfluorfen at 0-3 DAS	7.08 ^{b} (12.00×10^{6})	7.40 ^{a} (25.00×10^{6})	5.06 ^{c} (11.67×10^{4})	5.43 ^{a} (27.00×10^{4})	5.26 (2.00×10^{5})	5.40 (2.67×10^{5})
T_3 Oxyfluorfen at 0-3 DAS, *fb* HW at 25 DAS	7.17 ^{ab} (15.00×10^{6})	7.42 ^{a} (26.67×10^{6})	5.09 ^{c} (12.33×10^{4})	5.43 ^{a} (27.00×10^{4})	3.59 (1.67×10^{5})	5.26 (2.00×10^{5})
T_4 Imazethapyr at 0-3 DAS, *fb* HW at 25 DAS	7.16 ^{ab} (14.67×10^{6})	7.40 ^{a} (25.33×10^{6})	5.29 ^{ab} (19.67×10^{4})	5.46 ^{a} (29.33×10^{4})	3.59 (1.67×10^{5})	5.26 (2.00×10^{5})
T_5 Imazethapyr + imazamox at 0-3 DAS, *fb* HW at 25 DAS	7.21 ^{ab} (16.67×10^{6})	7.46 ^{a} (28.67×10^{6})	5.16 ^{bc} (14.67×10^{4})	5.40 ^{a} (25.67×10^{4})	3.59 (1.67×10^{5})	5.41 (2.67×10^{5})
T_6 Diclosulam at 0-3 DAS, *fb* HW at 25 DAS	6.87 ^{c} (7.67×10^{6})	7.13 ^{b} (13.67×10^{6})	4.99 ^{c} (10.00×10^{4})	5.10 ^{b} (13.00×10^{4})	3.53 (1.33×10^{5})	5.26 (2.00×10^{5})
T_7 HW at 20 DAS and 40 DAS	7.30 ^{a} (20.33×10^{6})	7.49 ^{a} (31.00×10^{6})	5.27 ^{ab} (19.67×10^{4})	5.49 ^{a} (31.33×10^{4})	5.31 (2.33×10^{5})	5.50 (3.33×10^{5})
T_8 Unweeded control	7.19 ^{ab} (16.00×10^{6})	7.44 ^{a} (28.00×10^{6})	5.35 ^{a} (22.67×10^{4})	5.48 ^{a} (30.33×10^{4})	5.31 (2.33×10^{5})	5.50 (3.33×10^{5})
CD (0.05)	0.17	0.13	0.18	0.14	NS	NS
Pre-experiment	14×10^{6} cfu/g		3×10^{4} cfu/g		1.67×10^{5} cfu/g	

* log(10) transformed values with original values in parantheses. In a column, mean followed by common letters do not differ significantly at 5% level in DMRT

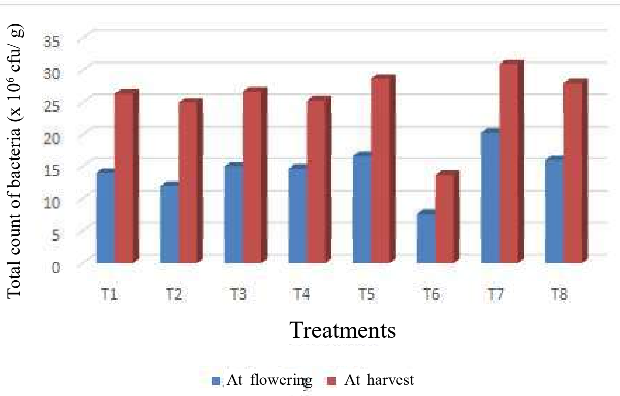

Fig. 3 : Effect of weed management practices on the total count of bacteria

highest in unweeded control, which was statistically on par with hand weeding, imazethapyr + imazamox *fb* hand weeding and stale seed bed (Table 3 and Fig. 4). At harvest, although the highest fungal count was noticed in hand weeding, it was statistically on par with stale seed bed, unweeded control, imazethapyr *fb* hand weeding, stale seed bed *fb* oxyfluorfen, oxyfluorfen *fb* hand weeding and imazethapyr + imazamox *fb* hand weeding, indicating that these chemicals did not produce any long-term effects on fungal population as well. Findings by Shruti *et al.* (2015) and Mahajan *et al.* (2020) also affirmed that the initial inhibitory effects of oxyfluorfen, imazethapyr and imazethapyr + imazamox on soil microbial population were later diminished with the gradual degradation of these herbicides. However, the soil bacterial and fungal populations were significantly lower in diclosulam *fb* hand weeding, which might be due to higher persistence of diclosulam in soil that eventually developed prolonged toxic effect on soil microbes. Jakhar (2011) and Deepa (2015) also concluded that the application of diclosulam resulted in a reduction in the population of soil bacteria, fungi and actinomycetes.

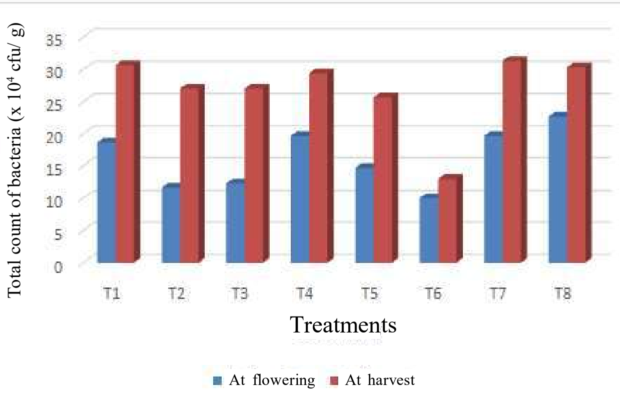

Fig. 4 : Effect of weed management practices on the total count of fungi

Soil Nutrient Status

Though unweeded control recorded lower soil available N as compared to the treatment plots, it was not significantly influenced by the weed management practices. Soil available P was significantly higher in hand weeding and was statistically on par with diclosulam *fb* hand weeding and imazethapyr + imazamox *fb* hand weeding. Similarly, available K was found significantly higher in diclosulam *fb* hand weeding which was on par with hand weeding, imazethapyr + imazamox *fb* hand weeding, oxyfluorfen *fb* hand weeding and imazethapyr *fb* hand weeding. The higher values of available nutrients might be attributed to the better weed control achieved in these treatments which led to a considerable reduction in nutrient removal by weeds, thus registering higher

TABLE 4
Effect of weed management practices on soil nutrient status

Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1 SSB for 14 days	113.40	46.56 ^{de}	112.20 ^{c}
T_2 SSB for 14 days, *fb* oxyfluorfen at 0-3 DAS	119.70	56.61 ^{cde}	204.60 ^{b}
T_3 Oxyfluorfen at 0-3 DAS, *fb* HW at 25 DAS	121.80	61.90 ^{cd}	257.40 ^{ab}
T_4 Imazethapyr at 0-3 DAS, *fb* HW at 25 DAS	123.90	64.73 ^{bc}	232.10 ^{ab}
T_5 Imazethapyr + imazamox (RM) at 0-3 DAS, *fb* HW at 25 DAS	140.70	80.07 ^{ab}	258.13 ^{ab}
T_6 Diclosulam at 0-3 DAS, *fb* HW at 25 DAS	147.00	82.72 ^{a}	310.20 ^{a}
T_7 HW at 20 DAS and 40 DAS	157.50	86.24 ^{a}	275.00 ^{ab}
T_8 Unweeded control	109.20	42.33 ^{e}	103.76 ^{c}
SEm (±)	-	5.64	27.16
CD (0.05)	NS	17.11	82.41
Pre-experiment	75.6	37.57	93.5

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT values for soil available nutrients. Malhi *et al.* (2020) observed that the adoption of chemical or physical weeding in black gram resulted in a significant reduction in nutrient uptake by weeds, as a result of which available N, P and K in the soil was increased. The lowest values of available nutrients were registered in unweeded control (Table 4), which might have been the consequence of increased nutrient removal by weeds observed in this treatment. This could be correlated with the studies of Komal and Yadav (2015) and Jinger *et al.* (2016), who found out that the nutrient removal by weeds in green gram was the highest in unweeded control whereas it was significantly reduced with the adoption of weed management practices. The longer deleterious effect of diclosulam on soil micro organisms was not reflected in the available nutrient content in soil. On the contrary, highest soil P and K contents were observed in this treatment, indicating that there were no consequences on soil fertility and soil sustainability.

Thus, efficient weed management practices which can successfully lower the weed dry matter production could result in maximizing the grain and haulm yield in green gram and show higher values of soil available nutrients as compared to unweeded control. Hand weeding resulted in the lowest weed dry matter production and the highest yield, however, the higher labour charges involved in manual weeding can create practical difficulties in adopting hand weeding on a large scale. Results of the present study indicates that the integration of any of the pre-emergence herbicides (oxyfluorfen, imazethapyr, imazethapyr + imazamox, diclosulam) with hand weeding also proves highly successful in achieving season-long weed control in green gram, thus making it a suitable alternative in conditions where manual weeding is scarce or highly costly. Although the application of pre-emergence herbicides resulted in a reduction in the soil microbial count at flowering as compared to the untreated plots, the population recovered by harvest stage in the plots treated with oxyfluorfen, imazethapyr and imazethapyr + imazamox. However, diclosulam was found to have a pronounced inhibitory effect on the soil microbial population at harvest as well, hence, more research on the residual effect of diclosulam on soil microorganisms is required before its recommendation as a viable weed control measure in green gram.

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