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Assessment of Yield Loss in Green Gram (*Vigna radiata* (L.) R. Wilczek) Cultivation and Estimation of Weed-Free Period for Eco-Friendly Weed Management †

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Abstract: Fabaceae member green gram (*Vigna radiata* (L.) R. Wilczek) is one of the most economically important grain legumes of traditional farming systems of Sri Lanka because of its cheap sources of protein, animal feed, and in sustaining soil fertility by fixing atmospheric nitrogen. Weeds are one of the major problems in mung bean cultivation, reduce the yield through competition, interference with harvest and harbouring pest and diseases. Controlling of weeds by applying herbicides definitely would cause unexpected damage to human health and abundant biodiversity of Sri Lanka. Therefore, an investigation was planned to evaluate the yield loss due to weeds and to determine the optimum weed free period to minimize the yield losses. Three categories of trial plots were established. Plot one was maintained to determine the effect of different weed categories on the yield of the mung bean, in second category weeds were continuously hand weeded and kept weed free, and in third, weeds were allowed to compete with mung bean until 2, 3, 4, 5, 6 weeks after cultivation. All the treatments were conducted in Randomized Complete Block Design with three replicates. The data collected on types of weed, category of weeds, number of pods, pod weight at 3–6 weeks after planting (WAP) were analysed using SAS 9.4 statistical package and DMRT was performed to know the best treatment combination at p value of 0.05. The results showed that average yield loss due to total weed populations were 54.77%. Yield loss due to grasses alone were 46.56% and significant, in comparison to broad leaves (16.49%) and sedges (18.01%) at $p < 0.05$, respectively. The data of plant stand count at 3–4 WAP were not showed significant difference among treatments. But biomass weight of 50 plants, number of pods in 50 plants and grain weight of 10 plants were found to be significant after 3–4 WAP in weed free conditions at $p < 0.05\%$. In the weed free in the whole season obtained higher plot yield was 1241.6g and this was significant when weed was competing after 4 weeks of planting (1083.3 g). According to the results of the present study, it can be concluded that the critical weed free period until 3 to 4 WAP. Maintaining of weed free period of 3–4 weeks is recommended to minimize the yield loss in the green gram.

Keywords: critical weed free period; mung bean; weed; weed competition; yield loss due to weeds

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1. Introduction

Green gram has been one of the most important grain legumes in the traditional farming systems of Sri Lanka. It has been one of the principal but cheap sources of protein and its importance as a component of the Sri Lankan diet has grown over the years. Green gram not only contains a high percentage of easily digestible protein, but it's essential amino acid composition is also complementary to our staple diet, rice. In addition to being an important source of human food and animal feed, green gram also plays an important

role in sustaining soil fertility by improving physical properties and fixing atmospheric nitrogen in the soil.

The local production of green gram shows a declining trend over the last two decades, and tt reveals that 49.8% of the total green gram requirement is still being imported (Department of Customs, 2012).

In this context, it is clear that increasing the production of green gram is a must to achieve the target of the government. Therefor increasing the productivity of green gram has been identified as an important imperative need in order to meet the country's requirement and assure self-sufficiency. Moreover, the benefits of increasing green gram production would be boosting the income level of farmers and fulfilling the dietary needs of the people in the country. However, in Sri Lanka there is a large gap between the actual yield and the potential yield of green gram due to various issues i.e., unavailability of nutrient rich soil, lack of quality seeds, unsuitable climatic factors, traditional cultivating practices, improper weed management etc. Among these factors the improper weed management and weed infestation cause the maximum damage to the crop and its production. Weed management is the vital constraints reducing the crop potentiality in green gram. Weed flora of green gram crop differ from region to region with soil conditions. Studying the weed diversity/dynamics is helpful to understand the dominance or absence of a particular weed species in a cropping system, and to estimate yield loss due to weeds, and is equally important propose better strategy for their management [4,5,11].

Critical period of weed interference for a crop is a measure of crop, weed and environmental interaction. Crop density, soil fertility and cultivar can be adjusted to obtain advantages on the crop over weeds in the mission of competition [8]. Critical period of weed control and crop competitiveness can be effectively utilized to develop economical and environmentally sound weed management practices [5]. The critical period of weed competition is an important consideration in the development of appropriate weed management strategies [9].

The information on critical weed free period (CWFP) for green gram in Sri Lanka is rare and enough experiments were not carried out to determine the yield loss due to weeds and critical weed free period for green gram in Sri Lanka. Therefore, it is needed to find out the CWFP for green gram. It is important to provide more precise information for mung bean growers about the critical periods for weed control for maximizing the yield.

Mentioned problems, a research investigation was carried out with objective of determine the yield loss due to weeds in green gram cultivation in DL1 region and to decide critical weed free periods in green gram cultivation.

2. Materials and Methods

The experiment was conducted during 2019/20 Maha season at Grain Legume and Oil Crop Research and Development Center (GLORDC), Angunakolapelessa which is located at Hambantota District in the Southern Province. Geographically, the experimental site is located at about 6.1660m North latitude and 80.90310 m East longitudes. The agro ecological region is DL1b (Low Country Dry Zone). The mean annual rainfall of the location is 1020 to 1050 mm and the average annual temperature is in the range of 28–310c. The soil type of experiment site was Reddish Brown Earth (RBE). Soil pH was around 7.0, Field capacity was around 35.55%. Recommended MI–5 variety which was released in 1982 was planted. The entire cultivation period of this variety is about 55–65 days. Moreover, this variety was selected because of its best adoptability to the region and widely grown by farmers in the dry zone Sri Lanka. The land was ploughed to the depth of 15–20 cm by using disk plough and harrowed two times to make a seedbed with fine tilth. Seeds were planted on well prepared levelled beds. The plot size was 3 × 4 m for experiment 1. Then 3 × 3 m size plots were prepared for experiment 2. Three days before seed establishment, basal fertilizer were applied to the plots according to the Department of Agriculture (DOA) recommendation and incorporated into soil (Table 4). Seeds were

treated with recommended fungicide. MI–5 variety was planted 40 cm aparted rows. Row spacing was 15 cm. Two seeds were planted per hill. After 2 weeks it was thin out in to one plant. All the fertilizer management practices were done according to DOA. Experiment plots were irrigated with surface irrigation. Ridge and furrow irrigation was done at 4 days' interval. After 3 weeks, irrigation was done at 7 days of interval

2.1. Experiment 01—Determination of Yield Loss due to Weeds in Mungbean Cultivation

Completely Randomized Block Design will be used as the experimental design with three replicates. The following treatments were tested in the experiment.

T1—Remove only grass and broad leaves from 2nd week to 6th week
T2—Remove only broad leaves and sedges 2nd to 6th week
T3—Remove only grass and sedges 2nd to 6th week
T4—Remove all weeds 2nd to 6th week
T5—Remove grass only 2nd to 6th week
T6—Remove broad leaves only 2nd to 6th week
T7—Remove sedges only 2nd to 6th week
T8—No weed control (total weedy)

Recommended cultural practices of DOA, except manual weeding, was followed. The plot size was 3 m × 4 m. Following measurements were taken in this experiment, such as, 1. Plant stand count at one month; 2.Weed count at 4 weeks after planting (WFP) and dry weight of weeds; 3. Weed count at 7 weeks after planting and dry weight of weeds; 4. Biomass weight of 10 plants; 5. Numbers of pods per 10 plants; 6. Weight of grain yields per 10 plants; 7. Weed species in the field. Weeds were hand pulled from one square meter of each plot after 4 and 7 WAS and then classified to grasses, broad leaves and sedges. Number and dry weight (at 70 °C) of weed species of each group was recorded. Randomly selected 10 Mung bean plants from each plot were harvested to determine bio mass accumulation, number of pods and pod weight (g)/10 plants

2.2. Experiment 02—Determination of Critical Weed Free Period in Mungbean Cultivation

The experimental design was a randomized complete block with three replicates. There were two sets of trails maintained in the experiments, first set of trail (increasing weed free period) consisted of weed free periods of 2 (T1), 3 (T2), 4 (T3), 5 (T4), 6 (T5) weeks from planting, total weed free (T6) and full season weedy (T7). In the second trail, the plots were maintained weed-free at the beginning, and then weeds were allowed to grow and prevail in different time period until the end of the cropping period. The second set of treatments (Increasing weedy period) consisted of weedy periods of 2 (T1), 3 (T2), 4 (T3), 5 (T4), and 6 (T5) weeks from planting were compared with T6 (full season weedy) and total weed free (T7). The natural weed populations were allowed to emerge and weeds were removed at one-week intervals in different treatment plots to maintain different weedy periods. The agronomic practices such as fertilization, insect and disease management recommended by the DOA to Mung bean were followed. The weeds were removed by hands during entire experimental period. Following measurements were taken in this experiment, such as 1. Plant stand count at one month; 2. Pod weight of 10 plants per plot; 3. Grain weight of 10 plants per plot; 4. Total grain weight per plot; 5. Weed data in each week.

2.3. Statistical Analysis

To analyze the data parametric and nonparametric statistical methods were used. Analyzes of Variance (ANOVA) by was performed using SAS 9.4 statistical package and DMRT was performed to know the best treatment combination at p value of 0.05.

3. Results and Discussion

The results of this current investigation on identification and categorization of weed species available in GLORDC, and determination of weed free period in Mungbean cultivation to reduce the yield loss are explained below.

3.1. Experiment 01—Determination of Yield Loss due to Weeds in Mungbean Cultivation

The data of plant stand count at 2 WAP were not showed significant difference among treatments. The data indicates that the populations in trials plots were even (Table 1). Biomass weight of 10 plants T1, T3, T4, T5 were highly significant with the values of 416.67 g, 416.67 g, 408.33 g, 400.00 g, respectively, and these plots were free from grasses and other sedges or broad leaves or all weeds. According to result, in which treatments were exhibited higher biomass weight (T1, T3, T4 and T5), in those plots Yield (Number of pods/10 plants, Weight of grain/10 plants) was significantly higher at $p < 0.05$ (Table 1). T1 and T3 were under the weed interference showed the least biomass weight. When considering data analysis always grasses removing plots biomasses were in good biomass level than others. Therefore, grasses were the prominent weed for Mungbean at GLORDC research field. Mungbean yield was shown to decrease with increasing time of weed interference for all weed species in several species-specific and mixed weed population studies, as is the case in all agronomic crops (Zimdahl 2004).

Table 1. Biomass and pod yield of 10 Mungbean plants collected from Research field.

Treatment	Plant Stand Count at 2 WAP	Biomass Weight of 10 Plants (g)	Number of Pods/10 Plants	Weight of Grain/10 Plants (g)
T1	77.33 ^{a}	416.67 ^{a}	260.00 ^{a}	146.20 ^{ab}
T2	77.00 ^{a}	350.00 ^{ab}	154.33 ^{b}	96.20 ^{cd}
T3	77.00 ^{a}	416.67 ^{a}	254.33 ^{a}	148.90 ^{ab}
T4	85.00 ^{a}	408.33 ^{a}	285.67 ^{a}	178.30 ^{a}
T5	86.33 ^{a}	400.00 ^{a}	213.33 ^{ab}	134.70 ^{bc}
T6	84.66 ^{a}	233.33 ^{b}	160.33 ^{b}	96.20 ^{cd}
T7	79.66 ^{a}	218.33 ^{b}	131.00 ^{b}	97.70 ^{cd}
T8	81.33 ^{a}	245.00 ^{b}	128.33 ^{b}	80.70 ^{d}
CV%	7.2	23.86	25.17	18.93
LSD (0.05)	10.2^{ns}	140.45	89.67	40.57

Values with the same alphabets are not significantly different according to the DMRT at 95% confidence interval.

Calculation for Yield Loss due to Weeds

Total yield loss of mung bean due to weeds was 54.77%. When calculated individual effect, yield loss were 46.26%, 16.49%, and 18.01% due to grasses, broad leaves and sedges, respectively. Yield loss due to grasses and sedges combination were 46.05%, Yield loss due to Broad leaves and Sedges = 24.46% and Yield loss due to Broad leaves and Grasses = 45.21%. When kept one type of weeds in a plot, removed the competition among the weeds. Allowed weed type grows more aggressively and reduce the mungbean yield with more power. When combination of weeds allowed growing with grasses, yield loss was increased than allowed individual group of sedges or broad leaves. Everman et al. (2008) reported that presence of weeds causes a negative effect on the mung bean yield [3]. Further, Agostinho et al. (2006) reported that yield losses in plants due to weed interference varied between 74 and 92% depend on the condition prevailed [1]. The loss in yield of mungbean pods due to weed competition ranged from 30 to 40% [2]. These finding validated present research findings. Naidu et al. (1982) estimated that nutrient (N, P and K)

losses due to crop weed competition were 38.8, 9.2 and 23.3 kgha^{-1} respectively [7]. Therefore, the findings emphasize the to removal the weeds is important to prevent the yield and nutrient loss.

3.2. Determine the Critical Weed Free Period to Increase the Yield

The highest value of pod weight in weed free condition was appeared in weed free in whole season (Control 1) in T7 because of there was no any competition in between mungbean and weeds. Treatment 1 was given lowest pod weight because there was competition in between mungbean and weeds. They compete for sunlight, water, nutrients and space. And also there was no significant different between T4 (Weed free up to 4 WAP) and T5 (Weed free up to 5 WAP).

Table 2. Weight of pods obtained from the trial of increasing weed free period**.**

Treatment	**Weed Free Period**	**Weedy Period**
	Pod Weight	**Pod Weight**
T1—Weedy in whole season (Control 2)	109.70 ^{d}	133.10 ^{a}
T2—Weed free up to 2 WAP	117.80 ^{cd}	124.90 ^{ab}
T3—Weed free up to 3 WAP	124.90 ^{c}	115.80 ^{abc}
T4—Weed free up to 4 WAP	127.40 ^{bc}	102.70 ^{bcd}
T5—Weed free up to 5 WAP	131.10 ^{bc}	99.60 ^{cd}
T6—Weed free up to 6 WAP	140.40 ^{ab}	84.40 ^{d}
T7—Weed free in whole season (Control 1)	152.10 ^{a}	83.60 ^{d}
CV%	6.26	13.26
LSD	14.39	25.10

Means with the same letters are not significantly different at α =0.05.

The highest value of total weight of pods was observed in whole weed free season (T1). So it was given highest value for total weight of pods in mungbean. There was no significant different between T6 (Weeds compete up to 6 WAP) and T7 (Weeds compete on whole season-No weeding).

Weeds compete with crop plants for growth factors and impair crops growth and productivity. However, crops as well as weeds are different in their competition effects [6]. The competition effect, even for a short period after Mungbean emergence, can harm crops and may result in severe yield losses and growth reduction which is in most cases unrecoverable and can't be overcome by the addition of higher levels of growth factors mainly water and nutrients [10,12]. The factors affecting the weakness of mungbean are short stature, low above ground canopy, slow growth and very shallow and small root system that show in competition. However, since weed population is rarely pure under field condition, but instead different weed species may form weed populations once at a time. Therefore, one of the main factors that affect weed competition periods is weed population composition, species relative densities and their spatial arrangements. Weed population however, is a composite of different species dominated by broadleaf weeds in the presence of certain narrow species that complement each other in their competition influence on mungbean crop. Results indicate that the longer the weed competition period, the higher the reduction in mungbean growth and yield with the lowest pod weight obtained from weed-infested plots for the entire growing season [6,11].

4. Conclusions

Grasses were the prominent weeds than Broad leaves and sedges for Mungbean at GLORDC research field. Mungbean yield loss due to natural mixed weed population of the tested location was 54.77% and among them yield losses due to grass alone was nearly

46%. But. Mungbean yield is decrease in some amount with the interference of the all weeds types.

There was no effect of weeds during early stages of mungbean cultivation up to two weeks from planting. When increase the weed free period results increased yield in Mungbean cultivation, but when considering the cost of weeding it is practicable to minimize the cost if weed free period maintained 4–5 WAP.

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