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Influence of Seeding Rate and Reduced Doses of Super Gallant Herbicide on Weed Control, Yield and Component Yield of Mung Bean

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ABSTRACT

Crop-weed competition has a profound effect on the seed yield of mung bean. We evaluated the effects of both the seed rate and weeding regime on the weed infestation and crop performance of mung bean. Two factors via seed rate (15, 25 or 35 kg ha^{-1}) and different doses of haloxyfop-R-methyl (0, 0.4, 0.8 and 1.2 L ha^{-1}) were included in the experiment. The experiment was implemented in a split-plot design accommodating seed rate in the main plot and doses of herbicide in the subplot with four replications. Mean data from the experiment showed that weed density and weed dry weight were significantly affected by seed rate: these two variables decreased with the increase in the seed rate ($p<0.01$). The seed rate significantly influenced plant height, number of pod per plant, biological yield and seed yield. Different variables that included: Plant height, number of pod per plant, 1000 seed weight, harvest index and seed yield were significantly influenced by variations of herbicide doses. Seed yield was significantly improved in dose of 1.2 L ha^{-1}. Overall, the interaction effect of seed rate and herbicide doses was not significant in respect to the plant characteristics except harvest index and seed yield. Nevertheless, a seed rate of 35 kg ha^{-1}, coupled with volume of 0.8 L ha^{-1}, illustrated the best seed yield. Therefore, crop competition can be explored as an effective alternative weed management strategy and achieving optimal yield of mung bean.

Key words: Crop-weed competition, seed yield, *Vigna radita* L., Weed control

INTRODUCTION

Weed management in mung beans is one of the main production concerns for growers, similar to other dry beans, has short stature and slow early growth and therefore is not a competitive crop with weeds. Weed species generally have better nutrition efficiency and typically dominates and weakens crop plants, which negatively affects plant morphology and eventually crop yield. In fact, compared with cereals, legume species generally have an open growth habit and a slow growth rate in the early stages of the crop cycle, characteristics that favor the emergence and growth of weeds (Smitchger *et al*., 2012). In particular, there is an initial slow growth phase during the first four weeks of the mung bean life cycle. This delicate period makes mung bean seedlings particularly vulnerable to weed competition and severely affects the seedling establishment. Therefore, insufficient weed control during the early growth period of mung bean may cause yield reduction. Weed interference in dry bean can reduce seed yield as much as 83% (Arnold *et al*., 1993; Malik *et al*., 1993; Chikoye *et al*., 1995) and can interfere with harvest efficiency and may cause staining and reduce seed quality (Burnside *et al*., 1994; Bauer *et al*., 1995; Urwin *et al*., 1996).

Herbicides are the dominant tool used for weed control in modern agriculture; they are highly effective on most weeds but are not a complete solution to the complex challenge that weeds present. The overuse of herbicides has led to the rapid evolution of Herbicide-Resistant (HR) weeds (Beckie, 2007; Egan *et al*., 2011; Powles and Yu, 2010). In modern weed science also emphasizes following an ecological approach based on keeping weed populations below threshold levels rather than eradicating them (Barros *et al*., 2007). Thus there is a dire need of reducing herbicide dose and incorporation of other methods of weed control. Crop density significantly influences the incidence of weeds due to their competition for resources. The use of the optimum crop density may increases the efficiency of herbicide and to exhibit the effective of weed management (Babaei and Saeedipour, 2015). Optimal plant density and weeding regimes need to be established to reduce crop-weed competition. As a general principle, a lower dose of herbicide may kill most of the target weeds under favorable conditions. Under less favorable conditions, a higher dose will be required and under unfavorable conditions even the highest doses of herbicide may still give unsatisfactory results (Medd *et al*., 2001). Hamill and Zhang (1995) reported that reduced doses of herbicides can control weed density sufficiently and lessen their damage below the economic threshold. Another study indicated that applying 25-40% of the recommended dose properly controlled weeds without serious reduction of yield (Talgre *et al*., 2004). Fernandez-Quintanilla *et al*. (2000) reported that the result of reduced dose application was satisfactory compared with the recommended dose. When applying the reduced doses of herbicides, more attention must be paid to the stage of crop and weed growth because younger weed are more sensitive to herbicides than the more grown ones. Auskalnis (2003) reported that achieving good results from reduced dose application is only possible when the herbicide is applied at the early growth stages of weeds. Haloxyfop-R-methyl (Gallant super) is herbicide that inhibit acetyl-CoA carboxylase (ACCase), the enzyme needed for fatty acid synthesis and subsequent production of phospholipids needed for cell membranes in plants. This herbicide can provide effective control of annual and perennial grass species such as *Panicum dichotomiflorum* Michx (fall panicum), *Echinochloa crus galli* L. (barnyard grass), Missing in list *Setaria viridis* (L.) Beauv. (green foxtail), *Digitaria sanguinalis* (L.) Scop. (large crabgrass), *Panicum miliaceum* L. (proso millet), *Panicum capillare* L. (witchgrass), *Elytrigia repens* (L.) Nevski (quackgrass) and *Zea mays* L. (volunteer maize) (Vencill, 2002). The aim of this study was to investigate the effect of seeding density and reduced dose application of haloxyfop-R-methyl and their efficacy to control weed and yield performance of mung bean. Our hypothesis is, increasing the crop's competitive ability against weeds through manipulation in seeding rate and combined with reduced dose of haloxyfop-R-methyl herbicide would provide superior weed management and recuperative the mung bean seed yield.

MATERIALS AND METHODS

Experimental details: Field experiment was conducted in 2013-2014 at the Shoushtar Branch, Islamic Azad University, Iran (32° 3' N, 48° 50' E). The climate is arid and semi-arid with a mean annual rainfall of 321.4 mm and the average of annual minimum and maximum 9.5°C and 46.3°C, respectively. The soil was a clay loam texture, pH of 7.4, soil electrical conductivity was 3.2 dSm^{-1} and 0.4% organic matter content. The available phosphorous and potassium were 10.4 and 155 ppm respectively. The experiment was performed according to the spilt-plot design with four replications assigning the seed rate randomly in the main plots, while the different doses of haloxyfop-R-methyl in the sub plots. Plot size was 5.0 m×5.0 m. The experiment was composed of two factor namely seed rate having 3 treatments: 15, 25 and 35 kg ha^{-1} and herbicide regime having four treatments; 0, 0.4, 0.8 and 1.2 L ha^{-1}. Herbicide applications were made to 2-3 trifoliate leaf broad beans with a CO_2-pressurized backpack sprayer calibrated to deliver 200 L ha^{-1} of spray solution at a pressure of 200/240 kPa using low drift nozzles (ULD120- 02, Spraying Systems Co., P.O. Box 7900. Wheaton, IL 60188). The boom was 2.5 m wide with six nozzles spaced 0.5 m apart.

Measurements and data analyses: Data on weed infestation were taken at the maximum flowering stage of the mung bean plant by 0.25 m^2 quadrate, placing it randomly at three different places in each plot outside the central 5 m^2 area that was kept for obtaining yield data. The weeds growing in each plot were identified by their type of their species and their density per square meter was counted. The weeds were dried at 60°C to constant moisture and then weighed.

Yield contributing characters such as plant height, number of pod $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight were recorded by placing 1 m^2 quadrate in each plot. Ten plants from each plot (excluding border plants), outside the central 5 m^2 area were collected randomly. Weed infestation data were collected from the central 5 m^2 area.

Statistical analysis: Data were analyzed as spilt-plot design using PROC MIXED in SAS 9.2. Treatment comparisons were made using Duncan's Multiple Range Test (DMRT). A p-value<0.01 was considered statistically significant.

RESULTS AND DISCUSSION

Effect of seed rate and haloxyfop-R-methyl doses on the density and biomass accumulation of weed: As the crop population brings competition for limited resources with the weeds, we tested different seeding rates to increase crop plant density as a measure to control weeds. The weed population was significantly affected by seed rate ($p<0.01$; Table 1). The highest weed density (m^{-2}) was observed in the area with the lowest seed rate (i.e. 15 kg ha^{-1}). The lowest weed density was recorded in the area with the seed rate of (i.e. 35 kg ha^{-1}). There were no significant difference in weed densities between areas with a seed rate of 15 and 25 kg ha^{-1}. In general, however, there was an inverse relationship between a decreasing weed density ($p<0.01$) and an increasing seed rate. The increased seed rate resulted in a higher crop plant population providing less space for weeds to grow and offering much higher competition for light, nutrient and other growth factors. These factors collectively resulted in lower weed density. A result of some study showed that increasing crop density was reduces biomass and seed production in wild oat (Roberts *et al*., 2001; Scursoni and Satorre, 2005; Lemerle *et al*., 1996; Olsen *et al*., 2012). Increasing seed rate of mung bean significantly decreased ($p<0.01$) weed dry weight (Table 1). The seeding rate also has a profound effect on the weed dry weight in mung bean. The highest weed dry weight was recorded in the seed rate of 15 kg ha^{-1} and the lowest was found in 35 kg ha^{-1}. There

Table 1: Analysis of variance of the traits under study

Variation source	Degree freedom	Plant height	No. pod $plant^{-1}$	No. seed pod^{-1}	1000 grain weight	Seed yield	Mung bean dry weight	Harvest Index	Weed dry weight	Weed density
Replication	3	3.32^{ns}	12.78^{ns}	1.06^{ns}	166.8^{ns}	35047.6^{ns}	51.12^{ns}	244.3^{ns}	404.35^{ns}	153.95^{ns}
Density	2	$503.82^{\times\times}$	$197.78^{\times\times}$	0.509^{ns}	59.16^{ns}	$139342.9^{\times\times}$	$258.48^{\times\times}$	38.9^{ns}	$2914.9^{\times\times}$	$3826.32^{\times\times}$
E_a	6	67.74	45.02	1.08	57.38	21715.9	41.83	68.3	201.39	208.79
Herbicide	3	$190.21^{\times\times}$	$204.69^{\times\times}$	0.726^{ns}	$150.94^{\times}$	$30377.9^{\times}$	71.73^{ns}	$243.6^{\times}$	$5988.85^{\times\times}$	$10275.95^{\times\times}$
H×D	6	11.89^{ns}	9.26^{ns}	0.372^{ns}	50.13^{ns}	11132.5^{ns}	10.71^{ns}	303.5^{ns}	$481.36^{\times\times}$	$635.29^{\times\times}$
E_b	27	11.23	14.15	0.985	37.8	8471.5	39.59	84.4	98.35	95.95
CV%		10.3	16.2	11.3	12.3	14.4	10.4	8.4	19.6	19.9

ns :Insignificant, ××, ×: Significant differences at the p = 0.01 and 0.05 levels, respectively were no significant difference in weed densities between areas with a seed rate of 25 and 35 kg ha^{-1} (Table 2). There are several reasons why there was a lower density of weed infestation in areas that had a higher seed rate. Arce *et al*. (2009) showed that areas with higher plant densities might have a competitive advantage over weeds due to fast canopy development. A higher seeding rate may keep the weed flora under check through a smothering effect (Mahajan *et al*., 2010). Mohler (1996) revealed that a higher seeding rate may provide a competitive advantage to crop over weeds because crop plants will absorb limited resources at a faster rate. However, an increased seeding rate may not always increase the weed competitiveness of a crop and greater intra-crop competition may arise. This may lead to negative effects on crop production, especially under stressful environmental conditions (Kirkland *et al*., 2000). Therefore, an optimal seed rate, along with some weed control, is frequently practiced. For instance, Khaliq *et al*. (2012) showed that higher seeding density and herbicide tank mixture furnished effective weed control in direct seeded rice. Different doses of haloxyfop-R-methyl demonstrated a significant effect on total weed density (Table 1) and the difference was more pronounced at 1.2 L ha^{-1}. Reduced rates of haloxyfop-R-methyl were relatively more inhibitory to grasses species as against broad-leaved. Application of haloxyfop-R-methyl at various doses was equally ($p \leq 0.01$) effective in suppressing DM and density of grasses (Table 2). These results suggest that the magnitude of suppression achieved in combination of higher seed rate (25 and 35 kg ha^{-1}) when the application volume of haloxyfop-R-methyl was 1.2 L ha^{-1} (Table 3).

Effect of seed rate and haloxyfop-R-methyl doses on yield related to characteristics of mung bean: A number of variables except number of seeds pod^{-1} were significantly influenced ($p<0.01$) by seed rate and reduced rates of haloxyfop-R-methyl: plant height, number of pod

Table 2: Effect of seeding rate and weeding regime on the crop characters of mung bean

H. treatments (L ha^{-1})	Plant height (cm)	No. pod $plant^{-1}$	No. seed pod^{-1}	1000 grain weight (g)	Seed yield (g m^{-2})	Mung bean dry weight (g m^{-2})	Harvest index (%)	Reduced weed dry weight (%)	Reduced weed density (%)
0	36.7^{b}	9.6^{b}	8.46^{a}	43.08^{b}	314.95^{a}	22.95^{a}	29.71^{c}	-	-
0.4	39.6^{b}	11.2^{b}	8.95^{a}	47.92^{ab}	361.65^{b}	23.48^{a}	34.68^{ab}	33.72^{b}	27.8^{c}
0.8	43.5^{a}	16.8^{a}	9.0^{a}	50.58^{a}	411.88^{a}	23.53^{a}	31.55^{b}	57.19^{a}	36.8^{b}
1.2	45.6^{a}	18.1^{a}	8.86^{a}	50.63^{a}	424.95^{a}	28.18^{a}	40.01^{a}	65.24^{a}	53.4^{a}
P. density									
15	46.5^{a}	17.73^{a}	9.0^{a}	48.34^{a}	276.95^{b}	28.2^{a}	35.6^{a}	22.41^{b}	17.43^{b}
25	42.22^{ab}	13.26^{ab}	8.81^{a}	49.81^{a}	460.63^{a}	25.2^{ab}	33.84^{a}	41.72^{a}	27.01^{b}
35	35.38^{b}	10.79^{b}	8.64^{a}	46^{a}	$397.5a^{b}$	20.24^{b}	32.53^{a}	52.99^{a}	44.07^{a}

Table 3: Effect of interaction of seed rate and weeding regime on the crop characters of mung bean

P. density (kg ha^{-1})	H. treatment (L ha^{-1})	Plant height	No. pod $plant^{-1}$	No. seed pod^{-1}	1000 grain weight (g)	Seed yield (g m^{-2})	Mung bean dry weight (g)	Harvest index	Reduced weed dry weight (%)	Reduced weed density (%)
	0	42.53	14.05	9.98	42.88	139.2	28.3	17.86	-	-
	0.4	45.1	13.65	6.09	47	314.65	27	42.55	19.7	20.89
15	0.8	49.43	19.5	8.78	51.88	324.8	26.3	45.56	19.97	27.15
	1.2	48.95	20.7	9.2	51.63	329.15	31.2	36.43	30.04	41.6
	0	35.68	11	8.1	45.13	340	24	29.35	-	-
	0.4	41.7	11.35	8.85	55	375	23.2	32.36	16.88	30.21
25	0.8	43.35	14.05	8.88	50.38	437.5	23.4	37.79	33.29	61.7
	1.2	48.15	15.15	8.75	48.75	437.5	30.1	30.62	57.85	74.95
	0	31.98	10.3	8.3	41.25	395.3	16.55	41.93	-	-
	0.4	31.95	11.7	8.95	41.75	465.65	20.25	29.14	46.83	50.07
35	0.8	37.78	13.75	9.35	49.5	512.55	20.9	36.69	57.14	82.74
	1.2	39.8	13.4	8.63	51.5	469	23.25	27.59	72.31	79.16
CV%		6.3	7.2	5.3	4.3	6.4	6.4	4.4	5.6	4.9
Significance level		NS	NS	NS	NS	0.01	NS	0.01	0.01	0.01

plant^{-1}, 1000 seed weight, grain yield, biological yield and harvest index, however interactions were not significant (Table 3). The number of pod plant^{-1}decreased with the increase of the plant density from 15 plant m^{-2}, to 35 kg ha^{-1}. The highest number of pod plant^{-1} (17.73) was recorded at the 15 kg ha^{-1} seed density. The lowest number of pod plant^{-1} was recorded at the 35 kg ha^{-1} seed density. The highest number of seeds pod^{-1} was produced at a lower seed density (15 kg ha^{-1}). However, there were no significant differences in seeds pod^{-1} among mung bean seed rates (Table 2). The highest plant height and biological yield was observed in the seed rate of 15 kg ha^{-1}, illustrating an inverse trend with rising seed rate. On the other hand, no significant differences were found in 1000 grain weight and harvest index among seed rates. Maximum yield was found in higher seed rate and this was due to a more dense plant population with moderately higher fertile flowers than that of lower plant population with a higher fruit set. There is a relationship between seed rate and yield related characteristics and our results closely resemble numerous extant research findings (Zhao *et al*., 2007; Lin *et al*., 2009; Mahajan *et al*., 2010). Increased mung bean yield by increasing the amount of seeding rate reflects the increasing competitiveness of mung bean in competition with weed. No significant changing was observed in grain yield with seed rates of 25 and 35 kg ha^{-1}. Increased seeding rate over of 25 kg ha^{-1} was reduced mung bean grain yield. Under dense populations due to reduced light interception and CO_2 accumulation, the overall yield may be limited. Baloch *et al*. (2002) revealed that under increased plant density, intra-specific competition for light and nutrient leads to a reduction in grain yield. Mahajan *et al*. (2010) showed that with increased rice plant density, beyond the optimal level, might lead to high dilution effect resulting in lower yield. On the other hand, lower yield at less-than-optimal densities is probably due to the inability to intercept maximum available light due to poor stand establishment. In fact, intra-specific competition due to different seeding densities may vary in their intensity and compensatory growth of individual plants, when grown at lower densities, results in similar grain yield over a broad range of densities (Bond *et al*., 2005). All measured traits except number of seed per pod and biological yield were significantly affected by the doses of herbicide and in most cases, increasing the dose of herbicide from 0.4-1.2 L ha^{-1} increased yield and yield components of mung bean (Table 2). Michael *et al*. (2000) reported that application of reduced doses of herbicide resulted in an increased soybean yield. Higher grain yield in herbicide treated plots may be an outcome of efficient weed control achieved there. These results are in conformation with those of Baghestani *et al*. (2008), Chhokar *et al*. (2008) and Santos (2009) who reported that herbicides offer sizeable increase in crop productivity corresponding to their weed control spectrum. Negative correlation of mung bean yield with weed density and biomass reflects negative implications of weed competition on final yield.

Interaction of seed rate and haloxyfop-R-methyl doses on the crop characters of mung bean: There was no significant variation in respect of crop characteristics among the treatment combinations, except for harvest index and seed yield. The highest grain yield was recorded in seed 35 kg ha^{-1} with a 0.8 L ha^{-1} of haloxyfop-R-methyl, while the lowest was in 15 kg ha^{-1} seed with no herbicide application. An increased plant density resulted in decreased biomass accumulation in terms of weed dry matter. It has been reported that increased plant density enhanced water-use efficiency and plant nutrition in corn. Thus, our results are in agreement with those obtained in green gram (Bayan and Saharia, 1998) and in maize (Martinkova and Honek, 2001). This study was prompted by the need for reliable and cost-effective methods for controlling weeds in mung bean production through simple combination of agrochemical practices. On the basis of our finding increasing the crop's competitive ability against weeds through manipulation in seeding rate, or increasing weed removal through the addition of selective weed control would provide superior weed management. Since early seedling growth is very slow in mung bean, our results support the use of increased crop-weed competition through increases in seeding rate.

In conclusion, the seed rate and weed density significantly influenced the plant growth and yield parameter. Based on our results the density optimized for mung bean to reduce weed population is more than 25 kg ha^{-1} seed. These results provide a reasonable base for suggesting that combined plant population of 35 kg ha^{-1} used with reduced rates of haloxyfop-R-methyl (0.8 L ha^{-1}) is economical and will raise net benefits to achieve crop yield potential. So, the utilization of below-labelled doses of herbicides can be an effective way of reducing pesticide inputs and costs in field crops while maintaining satisfactory weed control and crop grain yield.

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